Programme : Morphosis
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Master Thesis Explanatory Document

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How can spatial adaptability in architecture be improved using kinetic design strategies?
“It is not the strongest of the species that survives, nor the most intelligent that survives. It is the one that is the most adaptable to change.”

- Charles Darwin
Abstract

Architecture is commonly designed with the aim of providing a fixed, ideal solution based upon the assumption of future situations being certain, invariable and at a particular moment in time. Traditionally, architecture portrays a static stance with qualities such as permanence, sturdiness, and solidity. Conversely, it is pertinent to assume uncertainties in future building uses with evolution and time. Constant innovation and transformation in related disciplines should be embraced and buildings designed to reflect this. This project attempts to challenge and provoke New Zealand’s current architectural stance (Appendix 1).

Introducing movement addresses the issue of spatial adaptability by allowing more flexibility and control over the building environment. Movement is used as a tool that empowers and allows varying spatial characteristics to occur than a static version may permit. A morphing architecture provides users’ with new spatial experiences as well as improving and inspiring everyday lives. Motion has been explored in terms of anticipation, future change, and technology and material advancements.

As technology evolves it is fundamentally altering the way in which we design buildings. Technology and digitally driven devices - from sensors receiving real-time information from the world, to output devices which convert input data into motion, have the potential to develop architecture from its static stance to a transforming response reacting to emerging situations. In this era, we need to consider how the integration of computing and ubiquitous devices can co-exist with architecture.

This research project explores the possibilities of a future architecture utilizing movement; ultimately investigating the way a space can fit a programme in order to improve spatial adaptability. Research by design was employed to formulate a provocative bespoke solution which was largely determined by the site, immediate context, and a relationship with programme. More flexibility and control over spaces occupied for a short duration is ideal as opposed to the current mentality of ‘one size fits all.’


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To:

My Family – your support over the past 5 years has been invaluable.

Piet – you are my hero.

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1.0 Introduction:

Background and Research Question:

Inspiration from Theo Jansen’s *strandbeests* (beach beasts) allowed a reconsideration of movement in buildings and a reassessment of what a future architecture can potentially hold. Parameters were meticulously applied to the *beests* with Jansen’s belief being that

“the walls between art and engineering exist only in our minds”

- implying that existing boundaries in many fields should be questioned and pushed.

From this inspiration the research question evolved:

How can spatial adaptability in architecture be improved using kinetic design strategies?

Classification of Spatial Adaptability:

Adaptable spatial configurations are “created by moving physical objects that can share a common physical space.” Spatial adaptability is found in the flexibility of the space to accommodate various programmes.

For this project spatial adaptability is defined as spaces (interior and exterior) which have flexible usage in emerging situations.

Improved spatial adaptability is the ability for the architecture to intentionally provide numerous spaces of various fits and qualities, which have flexible usage in emerging situations without the averaging out of programmes.

Classification of Kinetic Architecture:

The classification of kinetic architecture covers a very large spectrum of associated fields.

Kinetic architecture is defined as the design of buildings in which transformative, mechanized structures change with climate, need or purpose.

Michael A. Fox’s definition is “buildings and building components with variable mobility, location and/or geometry.”

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Aims:

"Emotive Architecture [architecture that feeds on data] can lead to either higher or lower emotional levels. It effectively broadens the bandwidth of our experience of spaces, in both directions of our emotional spectrum."7

-Kas Oosterhuis

This project aims to research, understand and design a space (through research by design) where maximum spatial adaptability is achieved by employing kinetic strategies. The architectural solution was stimulated by an uncertainty of how buildings may be used in the future whilst challenging seminal ideas regarding movement and architecture. The building will respond to a changing programme with the various requirements being fostered through dynamic spaces of which there could be numerous appropriate iterations.

The purpose is to create a building which not only plays with the “beauty of motion”8 but will also be used to improve users’ experiences of spaces and everyday life. The architectural solution tests whether kinematics is a sensible direction for future architecture to progress. The merging of architecture with old ideas, theories, aspects of art, engineering, and technologies (existing and emerging) will contribute to achieving the aim and objective.

7 Kas Oosterhuis, Kas. Architecture goes Wild. (Rotterdam, 010 Publishers, 2002).

Outline of Project:

There are many buildings and spaces throughout Auckland which are not frequently used and where the programmatic requirements have the possibility of overlapping. A transformative architecture which can change and adjust to conflicting needs and that can house multiple programmes in a space will benefit Auckland economically, socially and culturally.

Applying kinetic systems to architecture (as opposed to art or product design) is challenging, predominantly because of the large increase in scale.

Investigations into kinetic strategies are used to create a conceptual framework for usable, flexible, dynamic spaces, which are easily changed and reversed to house a range of programmatic requirements and occupancy needs. Possibilities and limitations are explored, with the desired outcome being a building, or part of a building, which exhibits movement activated by programmatic and spatial adaptability. Research by design is used to seek an elegant solution to the question.

How a movable architecture can be integrated into a static context without rejecting motionless surroundings was investigated. Further lines of exploration included: the link between the street edges and the proposed building, the changeable public spaces generated, people movement, immediate surroundings, and the setting within the city. Initially the building took on a civic role to analyze how a given
programme would affect the aim, however, this was open to debate. Programmatic requirements and kinetic strategies were driving factors from the outset, with a high importance placed on establishing a relationship between the user and the building.

Mechanical issues were worked through in conjunction with engineers from other disciplines.

Sustainable issues will be a part of this project. Initially this is addressed by the notion of having one building which can adjust to varied programmatic requirements - as opposed to many buildings, reducing the need for more buildings and spaces, which result in ‘neutralizing’ the programme.

Parameters are critical for a more flexible typology of architecture as there is no set solution, but rather an outcome of process (as opposed to a static building). Integration of spatial adaptability and motion, combined with technological aspects may lead to seminal directions in which architecture may head.

Technology (existing and emerging) will be a large focus.
The constant evolution of technology is allowing movement to become more technically and economically attainable or feasible, in addition to perhaps changing the way in which buildings are viewed and occupied.\textsuperscript{10} Another similar field, ‘Interactive Architecture’, uses embedded computational technology which is becoming more visible through interactive facades, - (aspects of this technology, such as sensors, will be useful in kinetic architecture) whereas kinetic architecture is concerned with “modifying a spatial situation through altering volumes and moving objects.”\textsuperscript{11}

Movement inspires a new dimension in the way a participant experiences and interacts with a space or building and when done in real-time the experience is the most powerful. Exploiting kinetic strategies provides the opportunity to provoke architecture now, and for users and inhabitants to play the buildings ‘game’.\textsuperscript{12}


\textsuperscript{11} Kamman, “Adaptive Space,”1.

2.0 Define Project:

2.1 Literature Review:

The most important areas of interest relevant to this project include:

1. Spatial adaptability.
2. Kinetic transformation in architecture.
3. The “digital revolution.”
4. Sustainability and the future.

“Worldwide you can feel and see that kinetic architecture is the next step within a larger evolution where people and societies from all over the world are trying to connect.”

-Xaveer Claerhout

The increase in social and urban demands paired with issues of sustainability has brought to light the need for architecture to be flexible, changeable and adaptable to different situations.

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13 Claerhout, Kinetower + Exclusive Interview with Kinetura.
14 Fox and Kemp, Interactive Architecture, 18.
1. Spatial Adaptability:

According to K.G. Kamman there are three reasons why motion would be applied to contemporary static buildings. These are:

1. “visual means [...] for the beauty of motion,”

2. to control or influence the climate inside buildings, ... and

3. to improve the spatial functionality” [adaptability of spaces to changing programmes] - where it is necessary to modify a spatial situation through altering volumes and moving objects.”

Kamman investigates interior spatial adaptability through the contraction and expansion of interior walls, with the aim of the study being to fully utilize a space when in

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16 Ibid.
17 Ibid.
Potential for various programmatic adaptability applications arise from a proper understanding of what a current space is doing, and then how it could possibly do it better. Spatial configurations should derive directly from the event occurring, with the form being spatial enough to truly accommodate the activity.

William Zuk states that architecture “can be described as a three-dimensional form-response to a set of pressures.”

“Novel applications in spatial optimization arise through addressing how transformable objects can dynamically occupy predefined physical space.”

- Michael Fox and Miles Kemp.

Although the field of responsive spatial adaptability is relatively unexplored it has been noted that spatial efficiency and flexibility drives the desire to apply kinetic design to architecture. This gap noted provides this project with a strong direction in what research needs to be explored in more depth. It is common for a new visual aesthetic and form to be expected in a field which is relatively unexplored.

Spatial adaptability is based upon site and programmatic issues as well as changing needs, and ranges from full mobility, to complete structure transformability, as well as interior re-organisations. Christopher Alexander argues that it is not quite as simple as fulfilling changing needs; as needs, desires and other factors change over time, allowing new options and forms to be employed. A set of continually changing pressures (of which if one changes, the whole is affected) generates adjusting spatial configurations in a kinetic environment, optimizing the use of space. Pressures do not act in isolation, but rather


Potential for various programmatic adaptability applications arise from an understanding of what a current space is doing, and then how it could possibly do it better. Spatial configurations should derive directly from the event occurring, with the form being spatial enough to truly accommodate the activity.

William Zuk states that architecture “can be described as a three-dimensional form-response to a set of pressures.” This broad definition implies that the future potential of architecture has not yet been developed; and that it needs to be recognized that there is a relationship between form and pressure, – or more precisely


that form is a direct response to pressure.\textsuperscript{23} 

\textbf{Contextual flexibility} in terms of form and climate are just as important as \textit{programmatic adaptability} however, “rarely are the two combined into a single system.”\textsuperscript{24} 

However Lars Spuybroek argues that “flexibility can often result in an underdetermined architecture, in an averaging out of programme and equalization, even neutralization, of space.”\textsuperscript{25} The cube is an ideal example of neutralization of space, as a multi-purpose space it is general enough to house almost anything which results in an averaging out and homogeneity of all possible events. The implementation of such a general space for ‘spatial adaptability’ implies that all decisions have been made prior, as the architecture does not engage as situations emerge. Spuybroek believes “the problem of flexibility is not so much ‘to open up space to more possibilities,’ but the concept of possible itself.”\textsuperscript{26} The empty openness, previously implied in the cube, needs to be replaced by a solid vagueness. Vagueness allows clearly defined goals and habits for as yet undetermined situations. A behavioural vagueness needs to co-exist with an architectural vagueness; - a behaviour epitomizing constant grouping and regrouping, of coagulating into particular configurations and then abruptly liquefying, and regrouping into various other fixed states.\textsuperscript{27} Both rigidity and flexibility become prominent with this system. Architectural vagueness is exemplified through the addition of movement into the structure. Spuybroek’s beliefs provide a base on which to build this project.

\begin{itemize}
\item \textsuperscript{23} Zuk and Clark, \textit{Kinetic Architecture}, 5.
\item \textsuperscript{24} Fox and Kemp, \textit{Interactive Architecture}, 40.
\item \textsuperscript{26} Ibid.
\item \textsuperscript{27} Ibid.
\end{itemize}
2. Kinetic Transformation in Architecture:

“Kinetic Architecture”28 by William Zuk and Roger H. Clark was published in 1970, with many ideas being seminal at that time. This book has influenced the progression of transformation in architecture, as well as this project, as many ideas are fundamentals to kinetic architecture and are still applicable 41 years on. The authors had the vision to foresee where architecture could head and many of these predictions have been correct.

Xaveer Claerhout simply states

“the static city is becoming heritage.”29

The design of transformable spaces is not a novel idea since examples exist from the ancient times. (Appendix 2). Kinetic architecture has a relatively short history with the most progress occurring from the 1980’s onwards with the development of the computer (Appendix 3).

The prevalent application of transformable spaces has proved to be challenging due to the lack of technology required for simple, easy to use kinetic structures. Until recently the vision of building facades and elements being able to literally perform has remained a vision for many architects, primarily due to financial constraints and technological limitations. Projects built are often small in scale, a scale model, or highly visible with a big budget,30 although Chuck Hoberman and Santiago Calatrava continue to demonstrate that from a mechanical point of view, large scale kinetic architecture is possible.

Over recent years, technological advancements have steered the way towards workable solutions for transformable building elements within structures. This was led by research groups such as the Kinetic Design Group at M.I.T. (founded by Michael Fox in 1998) and Kas Oosterhuis’ Hyperbody Research Group. The leap forward was made possible through the groups’ research which developed various methods as well as producing working paradigms.

The development of a physically transformable architecture appears to be many years away, however, progress towards this vision has occurred in various building elements.

Fox has written numerous papers and books covering various types of kinetic and interactive principles with a particular emphasis on the modern technologies utilized in movement.

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28 Zuk and Clark, Kinetic Architecture.
29 Claerhout, Kinetower + Exclusive Interview with Kinetura.
Kinetic architecture is a very broad field and can be broken down into three general sub categories (Appendix 4):

- Embedded kinetic structures.
- Deployable kinetic structures.
- Dynamic kinetic structures – This research project sits under this category:

  “Dynamic kinetic structures also exist within a larger architectural whole but act independently with respect to control of the larger context. Such can be subcategorized as Mobile, Transformable and Incremental kinetic systems.”

A kinetic structural system has ways and means for operability which must work together for a successful solution.

- “Ways” are the kinetic movements which the building uses to morph. This project explores these ‘motions’ in more detail.

- “Means” are the impetus for activation and could include pneumatics, electrical systems etc.

Ways and means work in parallel.

Morphing architecture simultaneously involves embedded computation and kinetic elements. The co-existence of these systems allows for the environment to “respond, react, adapt, and be interactive.”

Pragmatic flexibilities enhance everyday activities and possibly suggest new ways in which users’ and spaces can interact to complete tasks.

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31 Michael A. Fox, Beyond Kinetic M.I.T

32 Fox and Kemp, Interactive Architecture, 46.
33 Ibid.
34 Ibid., 52.
35 Ibid., 27.
36 Ibid., 49.
3. The “Digital Revolution:”

“in spite ... of these technological developments, so far our built environment has largely remained a frozen static environment, incapable of adapting to changing contextual parameters.”

-Kas Oosterhuis and Lukas Feireiss

From literature it appears that a movement is currently occurring, known as the “digital revolution”, which explores kinetic architecture through digital technologies as purely theoretical paradigms. An unstable territory is being entered into, in which rich, innovative forms have emerged, however, the nature and intent of architecture is becoming altered as boundaries such as matter and data become more blurred. Architecture is becoming, to an extent, the coexistence of experimental investigation, computer robotics, and redefining of spatial paradigms. It is almost as if we are seeing what could potentially be the next ‘built movement’, by exploring it thoroughly prior to building. Oosterhuis has led the way with his ‘MUSCLE’ prototype, erected at the ‘Non-standard Architectures’ exhibition at Centre Pompidou, Paris in 2003.39

Significant factors that will influence the rate of development in kinetic architecture


include, technology transfer (and developments in other fields), materials, robotics, biomimetics and evolutionary systems. Other fields investigated identify promising technologies, which can be adapted and applied to architectural uses. Materials, technologies, fabrication, and manufacturing are benefiting from the influence of other related disciplines in both biology and scale. 

Technologies offering the greatest promise to architecture are those which can potentially generate innovative techniques.

The production of materials to meet specific criteria is possible at a molecular level. “Smart materials are inherently tied to a function of scale. Nanotechnology is a new area of research based on the control of matter on a scale smaller than one micrometer, as well as the fabrication of devices on this same scale.”

“Smart materials” are already incorporated into interactive architecture as sensors and detectors which offer an optimistic outlook for kinetic architecture. Technologies are developing at such a pace that the best we can do to predict the future is to look at what is unfolding around us.

Fox believes that “kinetic systems with embedded intelligence will expose new programmes and forms as this technology is incorporated into our everyday lives.”

Fox’s numerous papers cover various types of kinetic and interactive principles, as well as investigating modern technologies, applicable for movement and controlling movement in architecture.

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41 Ibid., 227.
42 Ibid.
43 Fox, *Sustainable Applications of Intelligent Kinetic Systems*, A.
4. Sustainability and the Future:

Sustainable and smart kinetic design is no longer seen as optional, but as a common sense practice.  
Robert Kronenberg pertinently points out that buildings which use fewer resources and can adapt efficiently to complex site and programmatic requirements, are particularly relevant to an industry increasingly aware of its environmental responsibilities.  
With sustainability becoming such a big presence in architecture, and generally in how we live, it is thought that kinetics is the next logical step in the progression of architecture.  Kinetics may address a small part in providing a solution to the growing need for the increasing density of the urban environment which, right now, stands static and fails to address escalating needs for differentiation through changeability, responsiveness, and dynamics.

Many projects of the digital revolution stay just that: digital.  The design process often taking inspiration from computer based information and real-time data.  The research addressed in this project extends the idea of the MUSCLE (addressed in precedents) by bringing an element of reality to the digital revolution.

The trends assessed, outline current knowledge, as well as where there are potential gaps.  Spatial adaptability in itself, as well as contextual and programmatic flexibility, remains relatively unexplored with the latter rarely being combined into a coherent system.  Spatial adaptability via kinetic transformations has driven the project, with the beauty of motion also being considered.  As building technologies advance, potentially developing a different more adaptable, sustainable and economic type of architecture, it is all the more valuable to investigate kinetic architecture as a future direction.  The project provides further research with the aim of contributing to the current state of knowledge and future research.

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44 Claerhout, Kinetower + Exclusive Interview with Kinetura.
2.2 Precedent Survey:

In general, it appears that much kinetic-based architecture tends to be explored through hypothetical works, often never becoming a reality. Most kinetic strategies of built projects are project-specific. Precedents have been analysed in terms of function, materiality, structure, technology, circulation, how movement occurs (ways and means), and surroundings of the building. Plans and details have been investigated where applicable.
**Strandbeests. - Theo Jansen:**

Artist: Theo Jansen.

Jansen is a Dutch artist who has developed the *strandbeest.* (Figure 2.4) Jansen has spent the last 21 years evolving a series of wind-powered animals, made of plastic tubes.

Structure and Movement: - The basic *strandbeest* design is comprised of multiple pairs of legs attached to a central crank-shaft. When the animals are fed by wind, they begin moving and transmuting into organic-looking creatures; or beach-animals as Jansen calls them. When walking, a galloping herd effect is produced with each leg timed to move so that the ‘body’ stays level and steady.

Parameters: - The *strandbeest* can sense dangerous territory, such as water and loose sand with a feeler, which sucks air, and upon a change in resistance i.e water, the *strandbeest* reverses away from the hazard. The ‘leg’ is made up of four four-bar arrangements. The resulting movement conveys the walking pattern of a four-legged animal. The makeup of the leg lengths and position of the crank affects the gait of the animal.47 (Figure 2.3)

1. Eight links per leg.
2. 120 degrees of crank rotation per stride.
3. Step height is primarily achieved by a parallel linkage in the leg that is folded during the cycle angling the lower portion of the leg.48 (Figure 2.2)

The next step for Jansen is to develop the *strandbeests’* brains so that they can think for themselves.49

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Figure 2.4: Jansen's *stranbeest.*
Trans-Ports Proactive Building Concept –
MUSCLE:

Architect: Kas Oosterhuis

The MUSCLE (Figure 2.6) is a programmable building with six modes being: artmode, officemode, networkmode, infomode, commercial mode, and dancemode.

Structure and Movement: - The MUSCLE is made up of pneumatic hydraulic space frames, which connect together with spherical joints allowing the space frame to move in three dimensions. (Figure 2.5) The space frame bars are adjustable in length and work together to morph in real-time, according to data received from the trans-ports game. Varying air pressure can change the length, height and width of the MUSCLE to one third of its original size. The space frame of the body can relax, become flexible, supple and bendable, but it will resist extreme forces and become as hard and strong as any permanent construction.

Materiality: - The interior and exterior material has to be truly flexible to follow the space frame structure. ONL developed a strong and elastic conceptual “3-d membrane, which expands and shrinks ... seam-lessly cocooning the moving structure.”

The MUSCLE eliminates the need for six static buildings, as the extremely flexible space alters for each individual mode.

“At the time “transports” represented an initial step towards the paradigm shift from frozen architecture to architecture in real-time ... transports” will be the first truly emotive building.” The structure becomes programmable and never stops calculating.

This precedent has been the most influential to this project, as it is based upon spatial adaptability, technology, movement and has an innovative aesthetic and form derived from the morphing of these aspects. A prototype of the MUSCLE has been constructed which brings elements of reality into this digital architecture. (Figure 2.7) This is architecture on the move, literally and through evolution.

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52 Ban, Trans-ports by Kas Oosterhuis.
53 Ibid.
54 Kas Oosterhuis, Architecture goes Wild, (Rotterdam: 010 Publishers, 2002), 44.
Figure 2.5: The adjustable MUSCLE space frame.

Figure 2.6: The MUSCLE.

Figure 2.7: The MUSCLE prototype.
Topotransegrity - Non-linear Responsive Environments:

Architect: Robert Neumayr.

This research project explores how the integration of an intelligent responsive architecture will impact on an urban space, and public life, essentially challenging architecture as a passive arrangement. Topotransegrity connects users, spaces and real-time performance criteria, whilst continuously assessing its surroundings via ubiquitous technological devices.\(^5\) By adapting to isolated spatial requirements (figure 2.9) topotransegrity challenges the notion of a static architecture.\(^6\)

Structure and Movement: - A six level, static structure contains an interlocking space frame system, (figure 2.8) which is powered by air driven pistons to drive reconfigurations.\(^7\) Parameters are applied throughout the process, so that critical issues such as circulation and pathway widths are practical. (Figure 2.10)

Test: - “The topotransegrity replaces the Barbican Arts Centre’s circulation spaces, connecting the remaining adjacent programme spaces with the existing entrance areas...”\(^5\)

Programme: - Topotransegrity has three modes being:

1. Programme Mode – “automates the basic functions of the structure. Directly related to the specific event schedule of its environment it drives the generic transformations, initiating and locating the deformations that control the access and the circulation within the public spaces. It also generates small emergent temporary spaces, which host ancillary programmes related to ongoing events.”\(^5\)

2. Crowd Mode – “responds in real time to the movements and behavioural patterns of the visitors within the structure. It influences the size, orientation and development of the temporary enclosures, previously established by the program mode.”\(^6\)

3. Memory Mode – “records, on a long-term basis, the paths and motion patterns chosen by individual users, influencing the surface topography by indicating and levelling the most frequented parts.”\(^6\)

55 Neumayr, Topotransegrity.
56 Ibid.
57 Oosterhuis and Feireiss, The Architecture Co-Laboratory, 432.
58 Ibid., 429.
The ideas of spatial adaptability, the extent of the movement, and differing programme modes were particularly useful for this project. Topotransegrity’s ability to configure to isolated spatial requirements, whilst not necessarily affecting the rest of the surface, is critical. However, it appears that there is an element of unpredictability in controlling the surface as the three modes run simultaneously and the spatial configurations are user-dependent.\textsuperscript{62} Control of the surface, and in fact any moving building / building parts, with both appropriate parameters and the ability for the user to override the computer is vital for success. It appears that a parameter applied to the surface limits movement to approximately 180°. This essentially affects the extent of movement in the surface.

\textsuperscript{62} Kas Oosterhuis and Lukas Feireiss, \textit{The Architecture Co-Laboratory}, 427.
**Miniature Calvin Klein Dollhouse:**

Architect: Joshua Prince-Ramus.

The Calvin Klein dollhouse is a window display “… the stylish dwelling spans 4 [sic] complete floors, including a landscaped urban rooftop, and is fabricated in steel, acrylic sheet, and four-way stretch Spandex.”

Movement: - Movement occurs through hydraulic linear actuators in conjunction with a hinging system. (Figure 2.11) The actuator restricts the movement of the planes to 180°. The tectonic approach has been to expose these elements so the viewer can see how the building moves. At this scale the planes are moved by hand.

The planning is based around four primary spaces: dining room, living room, bedroom and the pool deck which span over four floors. Essentially the spaces themselves are not changed when the planes move, but the atmosphere and views are altered.

The Doll-house sits as an object in space and has an elegant, futuristic appearance. (Figure 2.12) The material choice of spandex is well suited to the application as it stretches around the angles created by the structure and would affect how the Dollhouse appears in various light conditions. The ideas of materiality and elegance were particularly useful for this project.

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Figure 2.11: The hydraulic linear actuators move the planes.

Figure 2.12: The Calvin Klein Dollhouse.
Charles and Dee Wyley Theatre:

Architects: Joshua Prince-Ramus and Rem Koolhaas. REX / OMA.

The Charles and Dee Wyley Theatre is a “multi-form” theatre in Dallas. (Figure 2.15)

The 7700 m² theatre transforms between proscenium, thrust, arena, traverse, studio and flat floor configurations in a few hours; (figure 2.13) as well as opening the performance space to its urban surroundings. The theatre houses full front-of-house and back-of-house facilities and has a seating capacity of approximately 575, depending on the stage configuration.64

Dynamic kinetic structures are employed, - the structure remains static whilst kinetic elements exist within the larger architectural whole, but act independently with respect to control of the larger context. Vinyl blinds which are integrated into the windows themselves can be lifted to reveal the happenings in the auditorium behind, which also works in reverse so that the audience may be exposed to Dallas.65

The “theatre machine” transforms between a series of stage configurations with the push of a button and a small crew (two people) in a short amount of time.66 (Figure 2.14) Fail-safe technologies applied from other disciplines were used to help transform the theatre between stage configurations.67

Circulation and the “multi processional sequences” into the theatre were carefully designed so that patrons do not necessarily have to go through the “lobby architecture” to proceed into the theatre.68 Context was addressed by having the ability to open up portions of the ground floor to change the procession. All movement occurs on the interior with the building.

66 Ibid., 12.20 mins.
67 Ibid., 9.50 mins
68 Ibid.
Figure 2.14: Possible spatial configurations.

Figure 2.15: Charles and Dee Wyley Theatre - Dallas.
Schröder-Schräder House:

Architect: Gerrit Thomas Rietveld

The static Schröder-Schräder house, designed by Gerrit Thomas Rietveldt in 1924 consists of a ground floor divided into permanent separate rooms with a circular stair up to the first floor. The spatial arrangement is flexible, with the large space being split into a series of smaller spaces. Figure 2.17) Sleeping areas on the first floor are divided up by moveable partitions, which open up in the daytime to provide a large play area for the children and at night slide back to provide private bedrooms for the family. 69 This quality formed part of a manifesto of ideas valued by the De Stijl group in the 1920's. 70 Circulation depends on the location and position of walls. Sliding and revolving panels subdivide the space, and, when in an in-between state, a wide variety of possible variations can occur, each providing a different spatial experience. All movement occurs on the interior with the house remaining static. (Figure 2.18)

Context: - The Schröder-Schräder house is located next to a main street and contrasts the neighbouring property both in scale and materiality. The house appears quite out of context in comparison to its surroundings. (Figure 2.16)

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Figure 2.17: The spatial arrangement in plan.

Figure 2.18: The house remains static while the partitions slide.
3.0 Develop Project: Design / Research

3.1 Design Process:

Exploration 1.0:

The development of ideas taken from each subsequent design meant that the exploration happened in a sequence as opposed to various isolated enquiries. On occasions developments have led to a dead end with a back track necessary and a new approach sought in a process of ‘feeling’ the best way to advance. A systematic approach was achieved through the amalgamation of drawing in plan and section, as well as modelling both physically and in a 3D C.A.D. programme.

Initially, research would lead to a suitable site and programme, however, restrictions and constraints were needed upon which to base design decisions. The implementation of an experimental site and programme was executed in order to accept, or reject, ideas.

Critical analysis of the explorations was determined by the notions of spatial flexibility and variety, along with quality of spaces. Further developments progressed, after noting the positive aspects and issues of each investigation, ultimately resulting in a conclusion.

Exploration 2.0:

As well as a change in material a more structured approach was implemented which began with an investigation into motions / “ways.” A kinetic structure is based on the application of design principles that meet the function and aesthetics of the project. A selection of movements to be explored was drawn from the analysis of built and hypothetical projects. Model making and drawing was used to proceed. The motions were:

2.1 Hinge
2.2 Slide
2.3 Rotate / Pivot
2.4 Fold / Unfold
   2.4.a Expand and Contract
2.5 Magnetism

The inspiration behind this project was an object (the _strandbeest_), as opposed to a thought. It seemed logical to start exploring movement through models based upon the _beests_ by reinterpreting their movements. Balsa wood with pin connections was initially used to comprehend movement. However, the approach was quite unsuccessful in that subconscious parameters had been applied. The parameters consisted of movement being in one plane only, and unconsciously strips were used, rather than a surface, resulting in rather 2D models. Connections were difficult due to the choice in materials hence, a change in material was crucial. The parameters unintentionally applied early on were an important discovery as it reiterated the fact that all decisions in this process needed to be conscious.

The translation from verb to a spatial process came by initially creating conceptual models for each description. During this process, parameters were applied when necessary for a thorough and successful investigation.
Parameters added included the following:

1. A change to square card from rectangle. Initial rectangular planes did not relate to each other as a neat corner could not be formed, essentially offsetting each space. Square card was applied after requiring the hinge to stop at 90°.

2. Allowing the card to hinge 90°, 180°, or 360°.

3. Implementing two pieces of card to remain at a static 90°.

4. Forming a corner of a static cube with three pieces of card.

Hinging appears to be a very flexible motion and will become valuable to the investigation.

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Motion 2.1: Hinge:

Hinge: “A joint which holds two objects together whilst having the ability for one to swing relative to the other.”

Precedents which employ hinging include the Calvin Klein Dollhouse and to-potransegrity.

Hinging can be continuous, but is more often intermittent. Hinging requires parameters and once an axis has been defined, hinging occurs around that point in the same plane. The number of surfaces adjacent to the hinge affects movement. (Figure 3.1)

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Figure 3.1 Various spatial configurations are shown by a hinging hanger.
Figure 3.2 Hinging cube series.
The issues of some sliding configurations are similar to those of rotate / pivot being:

1. Sliding is limited to the initial number of spaces created.

2. When in the position of minimal use, the spaces are effectively occupied by another space, essentially making only the smallest space practical to use.

3. Issues when sliding spaces in, out, and through one another have massive repercussions involving weather tightness.

4. To move through and sit within one another, the spaces need to decrease in size from the largest; consequently room shapes are dictated by the biggest space, hence the goal of spatial adaptability may only be partially fulfilled.

5. Configurations for this project would need to be known in advance so that tracks can be laid to allow for the sliding, hence movement ends up being linear and predefined.

Sliding showed potential to be further developed.

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72 Ibid., “Slide.”
Figure 3.3 Sliding house.

Figure 3.4 Sliding series.
Motion 2.3: Rotate / Pivot:

There are two types of rotation in this sense.

1. “The act of rotating around an axis, and
2. the act of rotating an object itself.”

David Fisher’s Dynamic Rotating Tower is a residential installation of separate floors, rotating about an axis. (Figure 3.6)

The act of rotating around an axis (based on 3.7) proved to be very limiting, with similar issues to “slide” such as:

1. Only spaces created can become a space in itself, this being dependent on the position within the frame.
2. When in the position of minimal use, the spaces are effectively occupied by another space, essentially making only the smallest space practical to use. This motion would be viable if the spaces had to be completely folded away and made with as little material as possible.

3. When pivoting spaces in, out and through one another massive repercussions occur, such as weather tightness.

Vertically stacked pivoting produces similar results to David Fisher’s tower. Shape of the floor plates are the extent. Rotating around a core would only suit particular programmes.

Rotating an object itself is also a very limited motion. The object is essentially a static space, with predefined qualities. A small amount of spatial adaptability can be established with this movement.

Rem Koolhaas’s Prada transformer cube (figure 3.5) rotates as an object itself to accommodate a range of different fashion, art, exhibition and movie events. Spatial adaptability is accomplished here, but the floor plates and spaces created are a given.

In general the rotating / pivoting investigation was not successful.
Figure 3.5 Rotating Prada cube.

Figure 3.6 David Fishers pivoting tower.

Figure 3.7 Pivoting series.
Bodo Rasch’s Medina Umbrellas change in accordance to light levels shading the courtyard beneath.76 (Figure 3.10)

There are numerous opportunities for folding in architecture. However, the motion has often been applied to buildings as a static element. It appears that materials employed are supple and very light in weight, which implies that folding may be more suitable to temporary transportable structures, (figure 3.8) or as an embedded kinetic component. (Figure 3.9)

Folding and unfolding showed potential to be further developed.

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**Motion 2.4: Fold and Unfold:**

**Unfold:** 1. “To open or spread out from a folded state. 2. To reveal or be revealed.”74

**Fold:** “To bend double so that one part covers another.”75

A set method with rules helps to create a more defined and structural component. (Figure 3.9)

Folding is considered as one of the easiest motions to utilize, hence it is the most widespread. Folding surfaces transform interior and exterior spaces, though the difficulty of application increases for large-scale structures. (Figure 3.8) Folding is economical and usually straight-forward, reducing the use of complex parts, making maintenance easy.

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74 Ibid., “Unfold.”
75 Ibid., “Fold.”

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Figure 3.8  Folding at a large scale.

Figure 3.9  Set rules help to define folding.

Figure 3.10  Bodo Rasch's Medina Umbrellas.
Motion 2.4.a:  Expand and Contract:

Expansion and contraction motions are included as a separate movement sub-category of folding and unfolding. Their applications create different aesthetic effects which is crucial in architecture.

Expand: “To make or become greater in extent, size, or scope. To spread out; unfold.”

Contract: “To make or become smaller, narrower, or shorter.”

The motion of expanding and contracting usually uses common, folded frames. Complex geometrical relationships define the elements linear folding action, which creates unexpectedly expanding spaces. Chuck Hoberman has developed this movement, which has been applied on an architectural scale. (Figure 3.11)

Expanding and contracting motions appear to be quite restricting as the motion is primarily linear.

77 Collins English Dictionary and Thesaurus, “Expand.”
78 Ibid., “Contract.”
Figure 3.11  The Hoberman Arch.

Figure 3.12  Expand and Contract series.
**Motion 2.5: Magnetism:**

Janjaap Ruijssenaars’s Floating Bed (figure 3.13) is “...held up 40 cm by a permanent magnetic force due to the use of neodymium (NdFeB) elements in the floor as well as in the object. Thin steel cables assure it’s [sic] position...”\(^79\) This can hold up to 900kgs.

Magnetism: “The property of attraction [and repulsion] displayed by magnets.”\(^80\)

According to Zuk and Clark magnetism would allow change and increase the adaptability of kinetic structures.\(^81\)

Currently magnetism has not had an influencing effect on architecture in terms of building movement.

Magnetism still remains relevant to the enquiry.


\(^80\) Collins English Dictionary and Thesaurus, “Magnetism.”

\(^81\) Zuk and Clark, *Kinetic Architecture*, 45.
**Summary:**

The use of a single motion or a combination can create numerous possible variations of a kinetic structure.

Motions with the most potential were identified as being Hinge, Slide, and Fold / Unfold.

Investigations into the aforementioned kinetic strategies offered outcomes which provided a base for further explorations.
3.2 Experimental Programme:

3.2.1 - Site:

The physical restrictions and conditions of a site to inform and contain the design process was essential to decisions of what is required and how.

Site Analysis:

Site:

When choosing a site the principal consideration was the effect movement could have in activating a street edge. With this intention and the prospect of creating, or improving, issues such as pedestrian activity areas just out of city centres' that would benefit from being more connected to the city were considered.
Context:

The Sale Street area of Victoria Quarter is up and coming, with a large range of functions such as restaurants, bars, designers and architects. Sale Street is at the bottom of the hill, with a large incline towards the city. There is a highly apparent disconnection between Sale Street and Auckland City, with no sense of edge, along the southern side of Wellesley Street West. A stronger connection with an active street edge would benefit both nodes which could also potentially increase pedestrian activity. (Figure 3.15)

Site Analysis:

The selected site is on the corner of Nelson Street and Wellesley Street West, in Auckland, New Zealand. (Figure 3.14 and 3.16) Currently the site houses a very long and narrow car-park, which acts as a 'no mans-land' separating the two abovementioned nodes. (Figure 3.17) The difference in level over the length of the site is 11 metres over 94 metres, a 7° average incline. The site's area is 1512m². Site limitations will be essential for informing further design decisions and applying parameters.
Figure 3.16  Site locator plan.

Figure 3.17  Current site.

Former city council sheds.

Wellesley Street West.

City.

Victoria Quarter.
Rhubarb Lane:

Currently, there are plans to redevelop this city block into ‘Rhubarb Lane.’ The stage one proposal contains high-end, residential apartments which can be used as small commercial offices, and a boutique shopping area.\(^{82}\) The programme chosen must complement and enhance the existing and proposed functions of the immediate surrounding context, as well as take the entire Rhubarb Lane proposal into consideration. The Rhubarb Lane development “will be rolled out progressively over the next 10 years, [and] will eventually see 20 mixed use residential and commercial office buildings.”\(^{83}\) Further stages of Rhubarb Lane have not yet been developed; however, an initial conceptual design has been released. (Figure 3.18) The indications of building footprints, heights and mass have been used and it has been assumed that the programme will be similar to that of stage one. (Figure 3.19)

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\(^{83}\) Ibid.
Figure 3.19  Proposed ‘Rhubarb Lane’ development from Wellesley Street West.
History:

This city fringe block in general was formerly city council workshops which have long since been neglected.\(^{84}\) (Figure 3.17) Currently the sheds are used for a wide variety of functions, from hosting the NZ Fashion Festival to motorbike exhibitions. The majority of the project site is used for car parking and there is a small amount of planting. Currently the site is used as a thoroughfare for underground car parking to the south under what will become Rhubarb Lane. Once developed it appears that all car entrances to the site will be off Cook Street.

Climate:

New Zealand has a temperate climate with Auckland being near-subtropical; this results in varied and changeable weather conditions. The warm and wet climate brings hot, humid summers and mild, damp winters with high rainfall throughout the year, particularly during the winter months.\(^{85}\) New Zealand’s prevailing wind is a south westerly with a less frequent north easterly which often brings wind driven rain. Climate has been an important factor throughout the design process, with knowledge of the site’s climate being gained through time spent on site, and living in the near vicinity.

- Average annual rainfall: 1240mm
- Average annual sunshine hours: 2060
- Average summer temperature: 20°C
- Average winter temperature: 11°C\(^{86}\)
- Latitude: 36°51'S

\(^{84}\) Ibid.
\(^{86}\) Ibid.

Car Flow:

A motorway exit feeds onto Nelson Street, hence a very high number of cars use this arterial route each day, the seven day average being 26,184.\(^{87}\) Wellesley Street West is a secondary road, with a seven day average of 10,847 cars.\(^{88}\) (Figure 3.20) This corner site is in a highly visible location.

\(^{88}\) Ibid.
Figure 3.20: Traffic densities in the site vicinity.
3.2.2 - Programme:

An experimental programme was implemented to begin a process by which to understand the decision making procedure, apply ideas to observe outcomes and raise relevant issues and architectural concerns. When considering a kinetic programme, aspects considered were often time-based.

- Is the programme permanent, or does it stay for a short duration?
- Does it come, leave and then reappear?
- Is there a combination of functions that complement and enhance each other?
- Does it change daily, nightly, weekly, monthly, seasonally and / or annually, or with the weather?

It is vital for the selected programme to provoke change and generate opportunities and alternatives for the project.

Arts House:

The selection of an “Arts House” enhances the programmes of the surrounding context, as well as complimenting the future multi-use function of the Rhubarb Lane development.

The potential for flexibility is addressed through the requirement for various performance configurations and the associated back of house requirements. Different occupancy pressures and changing activities will demand multi-functional adaptable spaces.
The Arts House will include:

- Exhibition spaces (changeable – smaller, bigger, dividable)
- Performance spaces (changeable to different performance configurations – audience and stage)
- Cafe / Bar
- Art House movies
- Teaching / conference spaces
- Visual media spaces
- Workshops
- Outdoor air cinema

The programme will explore how a cross section of diverse Auckland arts can co-exist which include:

- Choir
- Dance
- Theatre
- Live Music
- Festivals

<table>
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<tr>
<th>Function:</th>
<th>Number:</th>
<th>Area:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exhibition / rehearsal / workshop / teaching and conference / and visual media spaces (changeable – smaller, bigger, dividable).</td>
<td>Exhib: 2 x 20m² 1 x 40m² 1 x 60-100m²</td>
<td>140 – 180m²</td>
</tr>
<tr>
<td></td>
<td>Rehears: 2 x 40m² 1 x 100m² 1 x 200m²</td>
<td>380m²</td>
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<tr>
<td></td>
<td>Performance spaces / Art House movies – Formal and Informal (changeable to different performance configurations – audience and stage).</td>
<td>Formal theatre: 150-200 seats 300m²  Playhouse: 60-100 seats 100 - 140m²  Informal theatre: 20-60 seats 30 - 75m²  Informal - less than 20 seats 30m²</td>
</tr>
<tr>
<td></td>
<td>Backstage area including WC / changing / greenroom / costumes / make up / props / fly tower etc.</td>
<td>Approx 300 - 400m²</td>
</tr>
<tr>
<td>Cafe / Bar.</td>
<td>1</td>
<td>30m²</td>
</tr>
<tr>
<td></td>
<td>Ability to house an outdoor air cinema in conjunction with Rhubarb Lane.</td>
<td></td>
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<tr>
<td></td>
<td>Total area required excluding circulation / WCs / plant etc 1310 – 1535m²</td>
<td></td>
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<tr>
<td></td>
<td>Existing Site Area 1512m²</td>
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</tbody>
</table>
Performance Spaces:

Performance spaces in Auckland tend to be exclusive, with the general public having little or no contact with the building on a daily basis. A function is generally needed in order to delve further into spaces. James Wenley states that the “Q Theatre ... brings some fresh hope ... But it doesn’t solve the problem that Auckland has a deficit of theatre venues. I’ll go further – we have a deficit of theatre venues with character.”

The proposed performance space is an opportunity to provide something that Auckland does not currently have and to create a new theatre experience which is innovative and breaks boundaries.

3.3 Design Process

**Exploration 3.0:**

This exploration took place primarily through plans and sections, with the ‘motions’ investigated being applied prior to exploration.

**Issues:**

1. Very restrictive in terms of:
   - The cubes only having straight axial movement.
   - The support columns standing within the space formed, when the walls fold back.
   - The prevalent long and narrow, and ‘L’ shaped spaces created, feel awkward and are not appropriate for the selected programme.
   - The spaces formed feeling very similar as the proportions of the space and roof height of each cube are constant.

2. Weather tightness being an issue at joints where the cubes connect together.

3. The goal of spatial adaptability is not fulfilled, as there is not enough flexibility for the various programmes.

4. The cubes portray Spuybroek’s theory of empty openness. Essentially all decisions for the spaces were made which ‘neutralize’ the programme.

**Exploration 3.1:**

“24 Cube Garage” - Sliding and Folding:

Cubes slide out of the ‘garage’ on a straight track, into the formation required. Once in place, they connect together and the walls fold back. The ground plane is divided into platforms, which can separately raise and lower on scissor lifts, breaking up the formation onto different levels.

When the cubes are in the garage the platforms and landscape become interactive. (Figure 3.21)
Figure 3.21 24 Cube garage plan and section.
**Outcomes:**

**Positive Aspects:**

1. The landscape can be used separately and simultaneously from and with the programme.

**Issues:**

1. The landscape is one piece; hence any movement is quite restricted as it affects the entire surface.
2. Spaces do not interact with the street.
3. Building does not activate the street edge.
4. The path through the length of the site needs to lead to the future Rhubarb Lane development as there is no point in making an alternative route for the foot path.
5. Movement in the landscape cannot be extreme as the surface covers the spaces below.

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**Exploration 3.2:**

**“Morphing Landscape” - Folding and Morphing:**

The programme is sunk below ground level with the landscape **folding** and morphing to create the spaces needed underneath. (Figure 3.22) The ability to use the roof as both a surface and a space was influenced by topotransegrity. The site would potentially become a large, public space co-existing with the programme beneath.
Figure 3.22  Morphing landscape plan and section.
Exploration 3.3:

Sliding Volumes:

Two large spaces each house two smaller volumes which slide in and out in either direction. Numerous iterations are possible. (Figure 3.23) This exploration reiterated the issues listed under slide (motion 2.2), and highlighted the fact that this particular approach to sliding was unsuitable for this project. These spaces contain more flexibility than the 24 cube garage; however, the same issue of “neutralizing” space threatens this exploration. These are general spaces with similar interior qualities, the architecture does not engage as situations emerge.

Outcomes:

Issues:

1. Very restrictive in terms of:
   - The spaces only having straight axial movement.
   - The spaces formed feeling very similar as the proportions of the space and roof height of each cube are constant.

2. Weather tightness being an issue where joints occur.

3. The goal of spatial adaptability is not fulfilled, as there is not enough flexibility for the various programmes.

4. The spaces portray Spuybroek’s theory of empty openness. Essentially all decisions for the spaces were made which ‘neutralize’ the programme.
Figure 3.23  ‘Slide’ conceptual model on site.
**Exploration 4.0:**

Massing was primarily used for this branch of explorations. The site was divided into three distinct segments with a function (cafe, exhibition or performance) strategically located. (Figure 3.25) The ‘motions’ investigated were separately applied to each function prior to exploration.

**Outcomes:**

**Issues:**

1. Once the programme spans over multiple floors issues of circulation surface. (Figure 3.24) (Appendix 5). This is not going to work if a volume hinges away completely from the mass for reasons of quick evacuation.

2. The smaller volumes need to be weather tight in themselves, or have some kind of system for weather proofing before they disconnect.

3. Extremely awkward exterior public spaces are formed when the mass is broken up. (Figure 3.24 and 3.26)

The exploration 4.0 series resulted in a dead end. A new approach was sought in a process of ‘feeling’ the best way to advance.

**Exploration 4.1:**

The performance mass was broken down into smaller segments which hinge away from the main volume, - some parts hinged out over the proposed Rhubarb Lane lawn. (Figure 3.24) Performances held in this segment can be viewed from the park.

Figure 3.24 Awkward public spaces result from the hinging mass. Issues of circulation arise from multiple floors.

Figure 3.25 C = Cafe
E = Exhibition
P = Performance

This placement of programme stems from traffic noise.
Figure 3.26  Theatre block mass series.
Prior investigations have primarily explored separate objects in space, which are joined together and prised apart using a ‘motion’ technique. These initial explorations raised issues and concerns in relation to structure and particularly weather tightness (Appendix 6). Structure has been considered throughout the exploration process; however, it has not been a driving force. This position has been established so that the form is not dictated by the perception of structural solutions that are available today. (Figure 3.27) The issue of how the exploration will stand structurally will not inhibit design decisions and will be addressed more thoroughly once a form has been found. The main concern of weather tightness has been addressed by adopting a new angle of approach with the implementation of a ‘top-down’ investigation.

3.4 The Top Down Investigation:

This approach required the whole site to be covered with a ‘roof’, which essentially weather proofs the space beneath. From here a process of working down was employed with walls modelled and spaces created. The top down investigation was successful, as it generated a different approach and various methods in which this project could potentially proceed.

Exploration 5.1:

“The Continuous Folded Roof.”

A continuous roof surface covers the site. Folds in the roof provide the ability for the planes to move, by being pulled up or pushed down to create spaces beneath. (Figure 3.28) Fundamentals of topotransegrity were exploited and a variety of spaces created. As previously mentioned the act of folding is one of the easiest motions to apply, consequently being widespread.
Outcomes:

Positive Aspects:
1. The initial form displays elements of beauty.
2. Solves initial weather tightness issues.
3. Displays elements of being an “architectural vagueness” - in keeping with Spuybroek’s beliefs.

Issues:
1. The extent of movement is restricted, depending on which side of the roof the cut is made (on top or beneath).
2. The smallest movement affects the whole roof.
3. The folds do not necessarily continue through to both edges of the roof, which restricts movement creating a more localized pull up and push down surface. (Figure 3.29) Hence spatial adaptability is not accomplished.

Figure 3.28 Top down concept.

Figure 3.29 Folds do not necessarily continue to both edges.
**Exploration 5.2:**

A continuous roof surface covers the site. Holes are punctured into the surface and infill shapes slide vertically within the void. (Figure 3.30) The spaces in the shape itself can open up and join together. On the ground the walls can fold away to create more various sized spaces of differing spatial qualities and shape.

**Outcomes:**

**Issues:**

1. Restricting as movement of the infill shape is vertical.

2. This exploration will not fulfil the aim of moving people along the street as the most enhancing view is probably from above or within the spaces.

3. This approach breaks the continuous roof structure, hence bringing up weather tightness issues.

4. A large shape looming overhead, which knowingly moves, could make one feel quite anxious when underneath.

5. Spaces and qualities are predefined “neutralizing” the architecture.

Figure 3.30    Void and vertically sliding shape.

Figure 3.31    Void and vertically sliding shape series.
**Exploration 5.3:**

A continuous roof surface, which is divided into parallel sections, covers the site. Each section slides vertically revealing the space beneath. (Figure 3.32) A more flexible variation would be to employ a Cartesian grid on the roof surface.

**Outcomes:**

**Positive Aspects:**

1. This exploration has relatively flexible space combinations and programmes can be divided into separate areas.

**Issues:**

1. This approach is very restrictive as there is only vertical movement.

2. Volumes can be joined together, however the actual overall shape of the spaces does not change, hence the aim of spatial adaptability is not fulfilled.

3. The roof space is unusable.

4. Weather tightness would have to be highly considered with this approach.
From the explorations into the motion of sliding, it appears that the initial issues (outlined in motions 2.2) have too large an effect on the architectural outcome as a “neutralization” of spaces occurs, as well as an “averaging out” of the programme. It appears that these issues mainly result from spaces that slide in, out and through one another. This defines the smaller volume, hence spaces end up having extremely similar floor plates, and volumes. Sliding will not necessarily be discarded, but will remain in the background.
3.5 Development of the Process:

Exploration 6.0:

Exploration 5.1 was developed based upon the positive aspects and potential of the “architectural vagueness.”
Exploration 6.1: Development of 5.1 - Roof Planes:

The **folding** movement in the surface was inhibited by being too localized and not having a big enough effect to provide a range of different spaces for the programme. (Figure 3.33) Progression was made by cutting through the folds in an off centre Cartesian grid system and using Sellotape as a makeshift hinge to reconstruct the surface so that each plane sat separately from the adjacent. This development made the roof more free-moving as the planes could **hinge** further, either up or down, relative to the adjoining plane. (Figure 3.34) The issue of weather tightness was immediately recreated with this decision. Neumayr’s topotransegrity is broken up in a similar way; however, the planes appear to be a generic shape, which creates smooth spaces and transitions. The spaces created by topotransegrity appear to be quite basic and portray a similar atmosphere and overall shape, – the antithesis of what is aiming to be achieved in this project.

![Image](image_url) Movement is localized, and affects the whole surface with a folding top down concept.
Figure 3.34  Movement of the surface changes with a hinging approach.
**Spatial Adaptability and Programme:**

**Exploration 6.2:**
Programme constraints and area requirements listed were used to trial how spatial arrangements could work together. This was tested by partitioning off areas under one roof (similar to a planning bubble diagram) to see how many programmes could occur simultaneously in one space, the space boundaries were then changed, and retested. (Figures 3.36) This exploration was based upon utilizing a type of wall system that would have characteristics to ‘reploy and deploy’. (Figure 3.35)

**Theatre area:**

Events that can occur in this space:
- Extra large formal theatre
- Formal theatre
- Playhouse
- Informal theatre
- Small informal theatre
- Walkway
- Large shelter
- Outdoor movie
- Big outdoor area, i.e. Farmers Market

Events which can occur simultaneously:
- Theatre and playhouse
- Theatre and informal theatre
- Informal and playhouse
- Formal, informal, and small informal theatres.
- Outdoor movie and playhouse
This investigation in conjunction with the programmatic requirements and site, established a very configurable roof arrangement in terms of spatial flexibility, fitting and determining programmes with similar requirements, and which events can happen simultaneously and how this can be achieved.

Outcomes:

Positive Aspects:

1. The hinges have created further movement in the roof, which has become more free-flowing

2. The form displays elements of beauty.

Issues:

1. The smallest movement still affects the entire roof.

2. Movement is restricted to a more localized pull up and push down surface, hence not accomplishing the purpose of spatial adaptability.

3. Weather tightness issues have resurfaced.

Figure 3.36 Potential spatial configurations of one space with different cuts.
**Exploration 6.3:**

The edge planes have different parameters to those roof planes surrounded adjacent­ly. (Figure 3.37) These edge planes can hinge up to 360° relative to the adjoining planes, thus instigating an exploration with the vision of roofs becoming walls and vice versa. This discovery was crucial to the process as it was found that separate more dynamic spaces could be formed within the larger roof plane, creating interesting public spaces adjacent to the street and adding yet more flexibility to the spaces.
Figure 3.37  The edge plane conditions are different to those surrounded adjacently.
Exploration 6.3.1: 
Defining Space through Cuts:

Possibilities for the creation of space are dictated by the number of cuts and, therefore, planes in the roof surface. The roof planes can simultaneously define themselves as partitions, suspended ceilings and floor surfaces. Defining how a space could be formed with these planes was investigated:

One plane – (on the ground or overhead) The ground plane against a contrasting background defines the space and edges that are created.\(^90\) (Figure 3.38)

An overhead plane offers a sense of enclosure beneath, with the edges establishing the boundaries. Qualities of the space are defined by the shape, size and height above the ground.\(^91\) (Figure 3.39)

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91 Ibid., 114.
One cut, with two planes creates a visually reinforced “space on which it fronts.”\(^{92}\) (Figure 3.40)

Two cuts, with three planes create a sense of enclosure, and visually reinforces the “space on which it fronts.”\(^{93}\) (Figure 3.41)

Three cuts, with four planes create a sense of enclosure. (Figure 3.42)

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92 Ibid., 121.

93 Ibid.
Spaces were created by hinging a plane over, and then over yet another plane, to create two, three, and four sided spaces in one direction. The off centre Cartesian grid allows the planes to roll over at differing angles, which produced spaces of varying sizes and qualities which can be used for numerous diverse functions. Bigger planes result from fewer cuts with the consequence being a more constrained movement, with less flexibility. Many cuts break the surface into small pieces, hence becoming extremely flexible, – topotransegrity comprises of many small surfaces which creates a smoother movement. This discovery will be used depending on the flexibility required beneath, which is determined by the programme.
A number of iterations were produced from exploration 6.3.1 to test for issues such as:

1. Spatial adaptability - The number of different versions that could be created in one area.

2. Architectural potential.

3. How the number, location and direction of cuts affect the quality of spaces created.

Each iteration experimented with an important aspect in regards to the location of the site being:

1. ‘Through paths’ connecting to Rhubarb Lane.

2. Habitable public spaces and the street edge condition.

3. The proposed Rhubarb Lane scheme and its immediate adjacent buildings.

The process of testing each version bought up unexpected iterations and errors.

With a clearer idea of space required, and aspects of spatial adaptability in mind, the roof planes have been further developed. The number, location and direction of cuts were continuously changed due to the spaces and forms they created. Spaces of various sizes and qualities are being sought in conjunction with a form which has qualities of elegance and clean lines.
Exploration 6.4: Roof Plane – Through Paths:

The Rhubarb Lane conceptual plan has distinct circulation through the site which will remain. (Figure 3.46) This is reiterated by the council’s requirement to have a path through the site linking the adjacent blocks to Fanshawe Street and Wynyard Quarter beyond. (Figure 3.43)

The connection through the site to Rhubarb Lane is critical, with through paths being implemented both short ways and longitudinally. This connection is not only a physical journey but also a psychological choice for the user to move through and be part of the building – at times even influencing the movement. The roof will morph to form these ‘through paths’ at different times (at least one through path will always be active). The through paths will be clearly defined through colour, form, and /or materiality on the ground, ceiling and roof surfaces. The transformation of spaces choreographs the visitor’s route through the building. A “smart material” - piezoelectric material (which generates electricity from pressure and vibration) will be used to collect the energy from the through paths, which, with the Rhubarb Lane development, has a prediction of moderate to heavy foot traffic. The electricity generated is used to subsidize power required to run the lights and motors.

The longitudinal through path runs over the building, connecting the corner intersection with Rhubarb Lane. (Figure 3.46)

Outcomes:

Positive Aspects:
1. Hinging allows movement to occur on a large scale.
2. A number of spatial configurations can be formed.
3. The power to run the lights is being subsidized by the foot traffic on the through paths.

Issues:
1. The smallest movement still affects the whole roof.
2. The through paths appear sloppy and unrefined. (Figure 3.48)
3. Weather tightness issues have resurfaced.
4. The cuts do not create interesting dynamic volumes, but flat, odd spaces.
Figure 3.44  Potential short through paths.

Figure 3.45  Potential short and long through paths.

Figure 3.46  The Rhubarb Lane circulation routes will be kept in approximately the same locations so the circulation will still work with the development.

Figure 3.47  Potential short and long through paths.
A short through path with two cuts restricts movement in that axis, and appears quite sloppy.

The number of cuts around the paths have been increased, placed closer and sometimes cross over each other forming an ‘intersection.’ The through paths need to be relatively flexible, hence smaller planes with increased movements will be employed to visually define the route through. (Figure 3.49)

Outcomes:

Positive Aspects:
1. The through paths appear more refined and visible
2. Movement is occurring on a large scale.
3. A number of spatial configurations can be formed.

Issues:
1. The smallest movement still affects the whole roof.
2. Weather tightness issues have resurfaced.
3. The cuts around the paths are allowing flexibility; however, the remainder of the surface still consists of odd shapes.
Figure 3.49  Through path movement and flexibility are increased by placing diagonal cuts across existing cuts.
Exploration 6.5: Roof Plane – Creating Habitable Exterior Spaces around Movement:

A static building creates permanent edges to adjacent spaces, whereas this project is the antithesis, generating new public spaces which disappear just as quickly. Consideration of exterior spaces on this prominent site has been high throughout the design process. The roof surface needs enough adaptability to provide a variety of spaces, varying in area and atmosphere. The main space facing north on Wellesley Street West is crucial as it creates the street edge condition and large events will be held in this sunny spot. (Figure 3.50)

The planes create numerous exterior spaces ranging in area from small to big, and protected to open with the scale of the planes, having a large impact upon the atmosphere created. (Figure 3.51) Like topotransegrity the interior and exterior spaces are affected by any plane movement – hence the amount of flexibility and configurations supported is numerous.

Outcomes:

Positive Aspects:

1. Numerous flexible exterior spaces with varying qualities are formed.
2. Movement is occurring on a large scale.
3. An increasing number of spatial configurations are created.

Issues:

1. The arrangement of cuts, paired with the issue of the main arterial route (Nelson Street), makes the western end of the site more usable.
2. The smallest movement still affects the whole roof.
3. Weather tightness issues have resurfaced.

Figure 3.50 The main Wellesley Street space.
Figure 3.51  The theatre roof hinges back creating new public spaces and blurring the street edge boundary.
Exploration 6.6:
Separating Sections of the Roof Planes:

The through paths break up the conformity of the roof and suggest locations for static pods, as well as areas of extreme or moderate flexibility. Separating sections of the roof so that they move individually will also solve the reoccurring problem of the smallest movement affecting the entire roof surface. The roof has been separated into two distinct sections which can sit at different heights. (Figure 3.52) This development has increased the flexibility in spatial configurations and programme. Planes that were previously quite restricted in hinging around adjacent surfaces would now behave more freely rolling in two directions. The option of hooking onto and unhooking from the main roof brings Zuk’s idea of “reversibility” 94 into the design. Zuk suggests that

“Materials ... must be so joined that they can easily be dis-joined. This latter feature is known as reversibility. ... Foundations too would have this capability of reversibility ...” 95

More flexibility was required. Consequently the roof was separated into three sections with a static pod adjacent to Nelson Street. (Figure 3.53) This will house the cafe.

Outcomes:

Positive Aspects:

1. Numerous flexible exterior spaces with varying qualities are formed.
2. Movement is occurring on a large scale.
3. An increasing number of spatial configurations are created.
4. The eastern end of the site is addressed by having a static pod which is capable of reiterating the corner, and forming a street edge.
5. Movement now affects the applicable section of roof.

Issues:

1. Weather tightness issues have resurfaced.


95 Ibid., 7.
Figure 3.52  The two separated roof sections.

Figure 3.53  A third roof section is separated for more flexibility.
Exploration 6.8: Walls:

A reinvestigation into walls brought up relevant questions – Could a wall system be deployed and reployed? Turned on and off? Or disappear and reappear? Reversibility in the walls will be used to achieve a flexible space. Wall systems investigated to separate simultaneous events were:

1. Water walls (Digital Water Pavilion) (Figures 3.54, 3.55, 3.56)
   - Uses high speed and frequency jets controlled by computers.
   - Senses people approaching and splits to let them through.

2. Air curtains and;

3. Vertically sliding windows or walls (Mies Van de Rohe’s Tugendhat House and Gerrit Thomas Rietveldt’s Schröder-Schräder house).

Figure 3.54 Digital Water Pavilion water wall.
Figure 3.55  The Digital Water Pavilion.

Figure 3.56  The Digital Water Pavilion.
3.6 Solution 1:

**Exploration 7.0:**

Two short through paths connect Wellesley Street West with the 6 metre wide pedestrian access-way between Rhubarb Lane and the building. (Figure 3.59) The long diagonal through path takes users over the building itself, (figures 3.64 and 3.67) again finishing the journey in the pedestrian access-way. (Figure 3.57) Currently users’ distinguish where the public through paths are by colour and materiality. These differentiations are experienced by a change underfoot (the long through path) or overhead (the two short through paths). The user’s experience of their journey is determined by the position of the roof planes in relation to the path.

![Figure 3.57](image) The black planes indicate the through paths.

![Figure 3.58](image) Solution 1: Basement level plan.
Figure 3.59  Solution 1: Ground plan.
These either:

- Enclose the path. (Figure 3.60)

- Frame the path, or; (figures 3.61 and 3.62)

- Completely open up the path. (Figure 3.63)
Figure 3.64 Section A - A. Long through path.
The roof configuration in the theatre area rolls away, revealing a public space which is variable in size. This can be joined to the main Wellesley Street public space creating the potential for an unlimited and varying number of uses. The north facing space is well protected and, when expanded, there are possibilities for the building to wrap around and shelter the extended Wellesley Street space, creating a protected haven from the prevailing winds. (Figure 3.65) The many spatial configurations for this external area will have a large impact upon the immediate urban vicinity, as well as the ‘life’ given to the space by users and events taking place. The boundaries between the building and the urban and public spaces will be slightly blurred as the ever changing roof planes will constantly morph this space. The street edge will be defined by a change in material underfoot; however, boundaries blur, depending on the building configuration.

Figure 3.65 Solution 1 - Public spaces.
The roof over the internal courtyard hinges over, providing optional cover to the cafe courtyard. This opens up the middle section of the building, creating the potential for events to overflow from the adjacent space, into the protected open (or covered) internal courtyard and down into the adjoining Rhubarb Lane courtyard. (Figure 3.66 and 3.67)
Figure 3.67 Section B - B.

Rhubarb Lane future development.
Figure 3.68  Section C - C.
**Static Pods:**

Anchoring the movement to the site led to three ‘static’ areas being formed. This was critical in creating an element of permanence and a regular constant. Presently the cafe is located on the corner of Nelson and Wellesley Streets, while the reception and control room are further down the site. (Figure 3.69) The third static area houses the back of stage functions and is located underneath the building. (Figure 3.58 and 3.67)
Outcomes:

Positive Aspects:

1. Good variety and flexibility of exterior spaces.

Issues:

2. This design is based upon flexibility for the current programme; however, not enough flexibility and dynamic spaces (especially in the exhibition area) were created in order to achieve the goal of spatial adaptability (re-consider the effect of having a programme).

1. The roof surface in the exhibition area is too constrained.

2. The long through path is oriented on a southwest to northeast axis. This is blocking the sun and enhancing the prevailing wind.

3. Form does not show the two short through paths clearly.

4. Entry to cafe does not feel correct.

5. Weather tightness issues remain.
3.7 Solution 2:

3.7.1 Reinvestigation of Programme:

The experimental programme instigated critical design decisions based upon form and planning. However, the true extent of flexibility was realized and raised the concern - that if this is genuinely a flexible piece of architecture, is it suitable to pin a programme onto it? Future programmatic uses cannot be foreseen, hence it is deemed inappropriate to have a fixed function. A forever changing programme of various uses has now been implemented with the spaces driven by and responding to the user's needs and desires, as well as pragmatic requirements, such as the human body. The architecture will respond to the spontaneous, the improvised and the accidental, with the role of the architect being to propose variations, rather than the choreography of the building.

Exploration 7.1:

The long through path has been re-orientated in an east west direction to limit exposure to the prevailing winds. To further minimize wind on the long path the idea of reversibility was utilized. The north-west corner plane was unhooked in one axis to protect the path in westerly winds; this is reversible in times of fine weather. (Figure 3.72) This plane reacts in real time to weather conditions. Through adding reversibility to selected planes, yet more flexibility is added in other positions; consequently the aim of spatial adaptability is increased. The reversible planes method has also been used to differentiate and show more clearly where the short through paths are located. The location of the static sections were revised, however, have remained in the same locations due to the site surroundings.

Figure 3.72 Northwest reversible plane.
The edge condition where two or more planes meet is crucial as this is where the hinge will sit, eventually determining the extent and flexibility of the planes rotation (ultimately affecting flexibility). The interior and exterior spaces are aesthetically affected by this connection so an element of fluidity is essential. (Figure 3.73)

The interior quality is enhanced by the recessed angles, shapes and sizes of the planes.
Flexibility and atmosphere of existing interior spaces was improved by modifying the number and angle of cuts, as well as the distance from an adjacent cut. The building has been separated into four separate sections to easily identify the section being discussed. (Figure 3.74) A new series of spaces and positions with different characteristics were generated for section four. (Figure 3.75)
Figure 3.76  New spatial qualities over the main Wellesley Street West space.
Figure 3.77  Section four - Selected spatial configurations.
The section two planes sharing an edge with the short through path were unhooked and issued with reversible properties. (Figure 3.78) The intention was to provide more flexibility; however, confined movement was still an issue with the spaces formed displaying similar spatial qualities to those in section four. In order to provide volumes with varying merits the spaces throughout the building must contain a diverse assortment of spatial qualities.
Structure has been considered throughout the exploration process; however, it has not been a driving force. This position has been established so that the form is not dictated by the perception of structural solutions that are available today. (Figure 3.79)

An aesthetic position on the mechanics of this building had to be taken in order to achieve the desired look of clean lines and elegance. The position taken was one of discreteness, which included parameters of:

1. All machinery, including motors, need to be located within the hinge, planes, or in a machinery ‘spine’.

2. The position of the hinge in relation to the planes can sit flush or slightly above or below the planes (up to 200mm from the top panel).

3. The mechanism needs to rotate the planes 270° around a point and be able to stop at any angle in between.

To achieve the aesthetic position stated, actuators and hinges are alternated to rotate the planes in relation to one another. (Figure 3.80)
Outcomes:

Positive Aspects:

1. Long through path aligned to an east-west axis and can be protected from winds at the westerly end.

2. The short through paths are more visible from the ground.

3. Outdoor spaces are protected and many variations available.

4. The interior spaces in section four have increased in flexibility, achieving the goal of spatial adaptability.

5. A fluid end condition has been designed.

6. The hinge has been designed.

Issues:

1. Cafe entry and static planning need to be revised.

2. Section two needs to be rethought in terms of flexibility.

3. Weather tightness issues remain.

4. The weight of the planes need to be calculated in order to correctly size the machinery required.
3.8 Solution 3:

Exploration 7.2:

The long through ramp finishing in Rhubarb Lane was revised, resulting in the ramp being extended past the development, ending near the main axis to the field. A stairwell will replace the ramp, descending into the pedestrian access-way. (Figure 3.76)

Extension of the roof to the east will provide a covered walkway along Nelson Street, indicative of the roof planes and atmosphere inside the building. (Figure 3.76)
The complete segregation of section two from the remaining roof surface created a series of new, flexible spaces dissimilar to those already formed. The roof acts more as an object in space, (figure 3.85) forming the walls and ceilings with the ability to hook back onto two, adjoining roof sections. Sections were used to test spatial adaptability which appeared to be highly improved by this change. (Figures 3.86 and 3.87) This exploration will need to be reinvestigated structurally.

Materiality and facades of the static pods are being considered in relation to the existing material palette.
Figure 3.86  Solution 3 - Section A-A.
Figure 3.87  Solution 3 - Section A-A.
Wind Loads:

Wind loads are addressed by a hydraulic arm system, of which numerous are located throughout the building. The system sits flush with the ground plane when not in use and rises when required. The pivot rotates to the applicable angle while the arm extends out to ‘catch’ the panel required with a hook and sensor on the end. Once hooked the arm ‘tightens’ to hold the panel in a fixed position. (Figure 3.88)

Street Furniture:

Street furniture, including seats and high tables, are inconspicuously located in areas of high utilization. Hydraulics raise and lower the furniture, with the surfaces sitting flush when not required. (Figure 3.89)
Material Palette:

The fields of aviation and aeronautics were influential in the selection of materials with a high strength to weight ratio being the determining factor - the smallest amount of material used achieves a minimum weight. Stiffness and durability were also highly important as there should be no flex in the plane itself. Materials with differing translucency and atmospheric qualities were investigated, as well as unobtainium (desired, but not yet available materials). Materials are frequently being developed and improved upon, thus becoming more suited to kinetic applications.

The planes are clad in fibre reinforced plastic in white gloss and matte black. Translucent fibre-glass honeycomb panel is used on selected planes, exposing the carbon fibre space frame (figure 3.80) and creating differing light qualities. An unobtainium similar to photovoltaic’s, but with clear properties is laminated onto the planes. Energy is collected and used to help subsidize lighting, and the electrically run motors which operate the actuators.
Grey tiles. Street furniture. Concrete. Light strips.

Figure 3.91 Material on ground plan.
The weight of each plane has been calculated by the elements which make up each piece. These include the tetrahedron carbon fibre space frame, materiality and an amount for titanium plates, bolts etc. A contingency amount has also been added. The aesthetic quality of the carbon fibre space frame is important as translucent material is used on various planes. The planes (figure 3.91) weigh 325 kilograms.

Outcomes:

Positive Aspects:

1. Long through path end locations revised.
2. A covered walkway in Nelson Street has been formed.
3. The interior spaces in section two have increased in flexibility, achieving the goal of spatial adaptability.
4. Static planning has been revised.
5. Plane weights have been calculated.

Issues:

1. The issue of structure in section two remains.
2. Size and power of rotary actuators need to be calculated.
3. Weather tightness issues remain.
4.0 Design Outcome:

4.1 Solution 4:

**Exploration 7.3:**

‘Spines’ have been strategically located throughout the plan to take the structure from the applicable perimeter planes down into the ground. Three spines are static and stay at a given height, whilst two spines in section two (figure 4.1) slide up when needed and sit flush with the ground level when not in use. Within the sliding spines there is a subsidiary spine, which raises straight up, and can also adjust to sit at an angle in the same axis. (Figure 4.2 and 4.3)

The section two roof has three edges which have been issued with reversible properties. Hinges sit on the outer edges and are joined to the pertinent spine when required. A critical parameter applied to section two is the need for the roof to join onto the subsequent spine before disengaging from the spine currently in use. The technology needed for this type of architecture and its scale is pushing the current technological and engineering boundaries.

The development of the sliding spine system has further increased the number of spatial configurations available in section two. The spatial qualities formed (figure 4.3) are different to those created in section four. The spines offer an element of permanence to the spaces; however, this quality is highly adjustable in section two. The development of the spine has helped achieve the project aim of improving spatial adaptability with kinetic strategies.

Gabion baskets with large greywacke rocks are used in the section four spines. Greywacke has been selected for a number of reasons:

1. Its texture provides relief to the hard linear properties of the other materials selected.
2. Big rocks have been specified so that large gaps are formed producing varying lighting qualities.
3. The wall will act as a heat store.
The planes join onto the sliding subsidiary spine allowing many spatial configurations.
The amount of torque needed to lift each section of planes was calculated in Newton metres. Rotary actuators were selected in accordance with the calculations. The preset torque of the actuators meant that each set of rows and columns was over calculated by a percentage. This is the contingency amount in case of a malfunction. (Appendix 7) Mechanical engineers were consulted during this process.

Weather tightness issues have been addressed by using an accordion-like membrane over the hinges. (Figure 4.4) This expands and compresses as the planes move, condensing the membrane to avoid excess fabric gathering in the hinge. (Figure 4.5)

The detail shown was used to resolve the recurring issue of weather tightness which developed from the initial decision to cut through the thickness of the roof surface, essentially changing the roof from a folding to a hinging system.
An unobtainium wall system is used to seal the spaces. Properties of the unobtainium include a malleable membrane which is magnetic, and has similar properties to that of variable tint glass. Unobtainium compresses into an exceedingly small volume to store in the flange of the planes. The membrane is deployed and adjusts to the space formed, by overlapping and bonding to adjacent membranes and the ground. It senses people approaching, and when parameters allow, it splits (similar to that of the digital water pavilion,) then subsequently rejoins.

Figure 4.6 Unobtainium wall system.
Outcomes:

Positive Aspects:

1. The spines structurally support the roof in section two. Interior spaces in section two have increased flexibility, achieving the goal of spatial adaptability.

2. Static planning has been revised

3. Rotary actuators have been selected by the power required to lift the relevant weight.

4. Weather tightness issues in the hinges are resolved.

5. Lighting has been designed in both the ground and the planes. (Figure 4.7)

Issues:

1. A wall system needs to be selected.
4.1.2 Design Outcome

Fundamental:

Parameters:

This project will not have an outcome as such, but rather a series of final forms as a result of the kinetic process. There are many design parameters which can be changed at any point, - from the amount of movement a plane has, to the behavioural characteristics of the building. With there being more than one variable, the number of forms over the lifecycle of the building is indeterminate in both extent and nature with potential for daily, weekly, monthly, seasonal, and annual iterations.
Modes of Operation:

Oosterhuis’s MUSCLE has six different ‘modes’ which the project morphs into. This specific mode approach does not work for this project as events which happen simultaneously will not necessarily be of just one ‘mode;’ hence the building will not necessarily return to a pre-programmed configuration. There will be hundreds of variations for the building to spatially reconfigure to, so a more general approach to ‘modes’ has been applied. The different modes can act together and independently to class similar input information and output behaviour. These are grouped into separate general ‘modes’ being:

ProgrammeMode:

The ProgrammeMode is the primary mode and purpose of the building. This is directly related to the data input and drives the required variations in the form. This is a private experience where the planes are used to enclose and define space. Circulation and public spaces derive from the ProgrammeMode.

RealTimeMode:

The RealTimeMode adapts the building to react to information and events gathered in real-time, i.e. at the same rate as they are depicted at. This information includes adapting to people movements (crowds, crowds in lines, groups or individuals), car intensity, light, climatic information, etc. in real-time. This mode is a constant and occurs simultaneously with the other modes.

WalkMode:

The WalkMode responds to information gathered in relation to user movement through the site. Real-time data, such as pedestrian numbers and route taken, allow the building to conform to the best ‘through path’ position at a point in time. It opens up as many of the three through paths as possible due to ProgrammeMode constraints. This is a public experience where the planes can frame views and lead viewers on a fluid journey through the building. This mode can be used by itself (when there is no data input) and in conjunction with the other Modes.

PlayMode:

PlayMode allows the buildings various characteristics to ‘play,’ for example the planes alternative use as a display skin. Information such as pictures, stories, text, short movie clips, webcams, outdoor movies and advertising (a prime spot with maximum exposure to Wellesley Street West) is transferred to the display skin and exhibited. PlayMode offers the means to provide extra revenue for the building.

RealTimeMode is always active while the other modes can behave independently, or in any combination which results in the buildings complex spatial configurations. The modes are always interrelated as they are based on the same data input information.
Collecting Information:

Sensors:

“...embedded computation (EC) is in a state of relative infancy. EC can be reduced to possessing a combination of both sensors (information gatherers) and processors (computational logic to interpret). EC is important not only in sensing change in the environment, but also in controlling the response to this change. The combination of embedded computation and kinetics is necessary to allow an environment to have the ability to reconfigure itself and automate physical change to respond, react, adapt, and be interactive.”


Sensors and wireless networks are integrated into the buildings structure and materials (in surfaces and edges) which, combined with the technology used, allows the transformation of the building into an intelligent operating system. These ubiquitous devices will be connected by wireless to the input mechanism which controls the building in real time. The vast number of sensors will solve the vital issue of objects (such as people) obstructing building movement in which case the building waits until the obstruction clears. Other external data will also be gathered, such as current and predicted climatic conditions, people movement and number of people.
Control System:

There will be a ‘partnership’ between the input device (which has its own intelligence of the building) and the users who will book space wirelessly or in person, with details such as area required and duration. The device will interpret and combine the information then transfer complex batches of data such as cross sectional profiles, dimensions and volumes, into a best possible configuration for a given moment in time. This includes the organisation of spaces, areas, needs and duration of the events whilst taking into account external time based data such as climate and people movement.

The need to override the control system is crucial, so the building (or parts thereof) can be controlled via manual data input. This is pertinent for isolated spatial requirements where the building is needed in a particular position, for a period of time, at a specific point in time. When there is no data input the building returns to the ‘best’ real-time neutral position by assessing external time based data. The building constantly re-evaluates this information, and changes accordingly, which affects its position depending on the time of day, day of the week, weather and seasons.

Data sent wirelessly to map boards throughout the site will let users know where and when events and upcoming functions are taking place.

Signals from the sensors are picked up by the input device which operates the hydraulic fluid valves controlling the rotary actuators in the hinges, movement then occurs according to the input and programme established. Every rotary actuator is activated by one specific valve which controls the oil to and from the actuator. This allows independent control of each hinge; however parameters applied ensure certain valves always work together.
Programme used to determine various spatial configurations whilst simultaneously taking into account other data. Used to time valve actions.

Piezoelectric material on through paths conveys information back to the control box.

Control unit. Derives input and drives actuators according to the programme.

Valves controlling hydraulic fluid to each actuator.

Hydraulic fluid flow and return hoses to other sections of roof.

Pump.

Motor with hydraulic oil.

Sensors linking back to the control unit are integrated into materials.

Rotary actuators distributed throughout roof sections.

Figure 4.8 Schematic of the rotary actuator system.
Structure and Technologies:

New structural technologies are constantly emerging, many of which have the potential to create innovative solutions for a more changeable architecture. Transformation, growth and change drive this technological development.97 The top down approach is based upon the building simultaneously being both structure and a mechanism in the process of transformation. The structural network spans distances, supports loads and provides shelter, whilst at the same time functioning as a mechanism by transferring forces and motion in a controlled manner. Each plane consists of a structural carbon fibre trapezoid space frame which connects to adjacent planes with hinges and flange mounted titanium rotary actuators, – the size and number depending on the weight to be lifted. (Appendix 7).

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5.0 Conclusion:

Summery and Appraisal:

Static buildings are indispensable; the city requires a constant, something that remains motionless whilst everything happens around it. Various programmes call for a frozen structure, whilst others are more adaptable.

This research by design project is a step forward in foreseeing and solving issues which are associated when movement is added to architecture.

“There is a possibility that form will no longer follow function, but form will become function.”98

-Amanda Parkes, Ivan Poupyrev, and Hiroshi Ishii

The building is site specific, with the immediate surroundings and information gathered determining its form. The structure expresses an ever changing choreographed architecture which moves in increments, with indeterminate spatial variations, most of which continuously return and are ‘recycled’. Prospective relationships between architecture and people have been revealed.

The challenge of finding the ‘best’ route of approach, particularly at the conceptual stage, revealed an unexpected solution with the roof planes being able to provide numerous spatial variations of different qualities. Opposed to the initial ideas, the spatial adaptability of the solution is in keeping with Spuybroek’s theory of solid vagueness. The solution supports and reiterates the basic ideas presented in the precedent and literature search.

“A bespoke atmosphere created by the building will be one of curiosity, joy, and taking the time to stop and enjoy beauty. Public interaction with this building, whether looking down onto it from above, walking over, past, or through or seeing it in PlayMode will leave a unique memory from the experience.

This project tests and suggests how architecture may transform and adapt with the digital revolution. A new aesthetic and form was naturally required. The final architectural solution is a radical approach / prediction, and, as controversial as it is, movement in architecture seems to be the next logical step in the progression of the discipline.

Future Directions:

The sustainability doctrine will play a huge part in any future architectural revolution. The goal of spatial adaptability immediately addresses this issue as the need for new buildings decreases if a space has the ability to appropriately house multiple changing programmes.

Throughout this research project issues were raised which required investigation into other disciplines. Aspects were solved by gaining an understanding and developing the information with research by design. Unobtainium materials and devices were considered for their properties which are perfect in all respects for the relevant applications, except that they do not exist.

Future directions for a kinetic architecture will require the chemical and mechanical development of materials and devices using micro and nanotechnology. Other fields will develop materials and when the properties match and the situation suitable they will subsequently be applied to architecture.

Zuk’s idea of reversibility has been revealed as another issue. Currently the project has some situations where technology is not advanced enough for the idea to work.

Kinetic elements are bespoke with an experimental nature, therefore, costing multiple times those which are static and standard. Issues which can be further addressed include visual and acoustic controls and privacy within spaces.

The reality of this project in the current era is not likely; however, once technology develops maybe the dream will become a reality.
... it appears that kinetic architecture is not at the beginning, nor is it by any means at the end; but it is, in a sense, at the end of the beginning.¹

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Figure 4.6  Unobtainium wall system.
Figure 4.7  Ground light strip detail.
Figure 4.8  Schematic of the rotary actuator system.

Figure 6.2  NZI - Auckland. Urbika, NZI Centre, http://www.urbika.com/projects/view/2738-nzi-centre
Figure 6.3  Lighthouse. Van Pouke, Lighthouse by Don Dunick in New Zealand, http://blog.kineticarchitecture.net/2011/01/rotating-lighthouse/
Figure 6.4  Wind wand - Len Lye. Len Lye's Wind Wand, http://www.flickr.com/photos/flissphil/132726619/.
Figure 6.6  Hinging ramp.
Figure 6.7  Weather tightness issues arise with sliding spaces.
Figure 6.8  Plan locating the rotary actuators.

Unless otherwise stated all images and photographs are the authors own.
8.0 Appendix:

Appendix 1:

From observation, New Zealand's current architectural stance is relatively reserved and very static. The latest notable buildings constructed in New Zealand focus on the sustainability issue, incorporating features which will gain points with the aim of achieving a five star rating under the New Zealand Green Building Council’s Greenstar system. However, the integration of *embedded kinetic systems* (see Appendix 4) with adaptive control is becoming more prevalent. Applications used lately include the use of night-time flushing (adaptive windows which open automatically at night to cool the building) and automatic blinds which adapt to the sun.

Ironbank utilizes an embedded kinetic system of windows on the east and west facades. The windows are on an adaptive control system, opening at night letting in cool air prior to the next day’s warm weather. (Figure 6.1)

Figure 6.2
NZI - Auckland.

The NZI building has an embedded kinetic system of blinds on the northern facade. The blinds operate on a fully adaptable sensor controlled system which includes preset stops, sun tracking and programmed scheduling to optimise the comfort of the building’s inhabitants all year round. (Figure 6.2)

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99 Fox, *Sustainable Applications of Intelligent Kinetic Systems*, 4.
New Zealand artist Len Lye was convinced that motion could be a part of art. Lye eventually became a central figure in the kinetic art movement. Lye's “wind wand” is a 45 metre high sculpture which sways in the winds next to the Tasman Sea in gusty New Plymouth.  

It appears that there is one piece of dynamic architecture in New Zealand being the “lighthouse” by Don Dunick. The house rotates around a central core tracking the sun. (Figure 6.3)

Figure 6.3  Lighthouse.

Figure 6.4  Wind wand - Len Lye.

Appendix 2:

“The built environment is commonly perceived as a relatively static entity, with change occurring slowly over years, decades and lifetimes, nevertheless; easily movable buildings were amongst the earliest artefacts made by human beings.”

101 Kronenberg, Transportable Environments 1.
Appendix 3:

A History of Interactive and Kinetic Architectures:

In 1832, Père Prosper Enfantin declared that

“Architecture as a theory of construction is an incomplete art: the notion of mobility, of motion, is lacking in it.”\(^{102}\)

- Père Prosper Enfantin

Since the times of Vitruvius, architects understood architecture as “the organization of space and time,”\(^{103}\) hence the first art to address and explore the suggestion of motion was painting. The idea of movement in architecture has predominantly been around for just over 90 years yet in the early 20\(^{th}\) century most kinetic design work was hypothetical. In 1919 Vladimir Tatlin designed a kinetic structure, the Monument for the Third Internazionale, where solid geometric objects wound on rails up a tower rotating at a speed of one rotation per day, month or year.\(^{104}\) (Figure 6.5)

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103 Jormakka, *Flying Dutchmen: Motion in Architecture*, 5.

The ‘launch’ of kinetic art was in the 1920’s with the 1950’s and 1960’s being the most prolific period. The 1950’s saw the development of sensors with remote signalling and the invention of the ‘remote control’ helped users to have more power over environmental control systems. In the 1960’s, Gordon Pask, amongst other cyberneticists pushed forward to recognize and comprehend interactive architecture as a field. This era saw the progression of system management change from the control room used in the 1950’s, to a control panel which notified users of problematic parameters. Archigram’s Ron Herron’s hypothetical vision of the Walking City in 1964 drew inspiration from the future and technology, and in 1970 Zuk published his book “Kinetic Architecture” which inspired architects of the time to design actual working kinetic buildings. The 1960’s and 1970’s saw seminal ideas created to advance an architecture of future ambiguity and emerging situations. These were based upon transformable buildings which offered a number of variations that could be selected by the user and were dependent upon future demands and circumstances. Development in the field of computing in the 1980’s and 1990’s would increase further exploration into motion and make funding for projects more viable. The combination of this period and newfound computer technology formed fields such as ‘interactive architecture’ where embedded computation and communication technologies could generate seminal, computationally enhanced environments. In the late 1990’s an assertion was made that the performance of architecture could be more successful if the newfound

106 Ibid.
computing technology could be used in conjunction with the idea of being able to physically adapt. From this declaration the history of kinetic architecture was re-examined with an understanding of what could be achieved with the latest computer technology, robotics and electronics. With the development of wireless networks and embedded sensor computation technologies in the 1990's, interactive and kinetic architectures have gained momentum, particularly as ideas become more technically and economically feasible. Technology appears to be the driving force behind kinetic architecture and it is this which is primarily restricting the speed at which architecture can be revolutionized.

The implications which this technological revolution may bring are still unforeseen and, whilst this is occurring, the field of architecture continues to quickly transforming and developing. From the design process to virtual realities, the evolution of architecture through the computer means that it is hard to take a step back, initiating us to look forward to what the future may hold.

"Music has already undergone the transition that architecture now faces...its entire theoretical, compositional, and performative logic had to be revised."  

-Marcos Novak

Appendix 4:

Embedded Kinetic Structures:
“Embedded kinetic structures are systems that exist within a larger architectural whole in a fixed location. The primary function is to control the larger architectural system or building, in response to changing factors.”109

Deployable Kinetic Structures:
“Deployable kinetic structures typically exist in a temporary location and are easily transportable. Such systems possess the inherent capability to be constructed and deconstructed in reverse.”110

Dynamic Kinetic Structures:
“Dynamic kinetic structures also exist within a larger architectural whole but act independently with respect to control of the larger context. Such can be subcategorized as Mobile, Transformable and Incremental kinetic systems.”111

109 Fox, Beyond Kinetic, 3.
110 Ibid.
111 Ibid.
Appendix 5:
If a building is more than one floor issues of circulation surface. An initial idea to solve this was a hinging ramp. (Figure 6.6)

Figure 6.6  Hinging ramp.
Appendix 6:

Weather tightness issues arise when spaces move in, out and through one another.

If an object moves through a space, disengages, and moves apart from the original object the entry and exit points need a viable solution to keep the weather out. (Figure 6.7) The solution needs to be highly flexible so that it can be stored efficiently and deployed quickly.

This approach generated mainly independent objects in space.
Appendix 7:

All motors are Helac L30 Heavy Duty Series:112

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Figure 6.8  Plan locating the rotary actuators.
9.0 Final Presentation:
Programme: Morphosis consists of roof planes which hinge to create multiple spaces, allowing the building to morph and change in response to changing audience dynamics. The result is a more precise 'fit' between the building and the isolated spatial requirements of the programme.
Programme: Morphosis

Section 1 - 1 [Fashion show] Dynamic programme: static audience

Section 2 - 2 [Fashion show] Dynamic programme: static audience

Section 3 - 3 [Sculpture exhibition] Dynamic programme: dynamic audience

Section 3 - 3 [Wine tasting] Static programme: dynamic audience

Section 3 - 3 [Community meeting] Static programme: static audience

Section 3 - 3 [Ballet rehearsal practice] Dynamic programme: static audience

Programme: Morphosis consists of roof planes which hinge to create multiple spaces, allowing the building to morph and ... The result is a more precise 'fit' between the building and the isolated spatial requirements of the programme.
Programme: Morphosis consists of roof planes which hinge to create multiple spaces, allowing the building to morph and ... The result is a more precise ‘fit’ between the building and the isolated spatial requirements of the programme.
Programme: Morphosis consists of roof planes, which hinge to create multiple spaces, allowing the building to morph and adapt to specific programmes. The result is a more precise 'fit' between the building and the isolated spatial requirements of the programme.
Programme: Morphosis consists of roof planes which hinge to create multiple spaces, allowing the building to morph and... The result is a more precise 'fit' between the building and the isolated spatial requirements of the programme.

Circulation through the site

Static areas

Pedestrian accessway - Rhubarb Lane

Perspective 3 - Wellesley Street West  - through path and public space

Perspective 2 - Wellesley Street West  - childrens' dance class in the main Wellesley Street space

Wellesley Street West

Nelson Street

Cafe

C.y.

Int. C.y.

Function

Room Kit.

Recep.

Control Room

Off.